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GREENHEART: A TIMBER WITH EXCEPTIONAL QUALITIES

By A. K. ARMSTRONG
Engineer in Forest Products

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NOTE

The following report by Mr. Armstrong was published in 1915. Since that time no further investigation of the subject has been made by the Forest Products Laboratory.

In connection with the resistance of greenheart to marine borers the experience of the Panama Canal is of interest. Greenheart was used in 1912, 1913, and 1917 in various ways in the locks of the canal. In 1922 much of this material had to be removed on account of destruction by marine borers. It is evident that greenheart is by no means immune to attack by marine borers in tropical waters. In northern waters, where marine borer activity is usually not so severe better results should be obtained, but the Forest Products Laboratory has no information on which to base an estimate of the number of years service that may reasonably be expected from greenheart in the different harbors of the country.

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GREENHEART -- A TIMBER WITH EXCEPTIONAL QUALITIES

By

A. K. Armstrong, Engineer

It is an odd circumstance that greenheart (Nectandra rodioei Schomb) is a timber almost unknown to the engineers of the United States. Before its recent use in the construction of the lock gates and dry docks of the Panama Canal it was practically unknown in this country, even by name, although it has been in extensive use abroad for more than a hundred years. Its undoubted value to the engineering profession is exemplified by its numerous good qualities. Its strength as a post or beam and its stiffness are considerably higher than that of the strongest and stiffest of the 130 North American woods so far tested at the Forest Products Laboratory. It contains heartwood that is almost immune to decay, and which is probably more resistant to the teredo and other marine wood borers than any of the hundreds of species of timber so far used as piling. In Europe it is generally considered of more value for lock-gate construction and piling than iron, or timber of other species, and finds extensive use in many places where a material of great durability and resistance to the marine wood borers, coupled with other highly desirable physical and mechanical properties, is desired.

It is the purpose of this article, published in two parts, to aid in introducing this timber to the engineer through a full review of its properties and uses, and such other information upon it as the writer has been able to collect from numerous sources.

Greenheart Logged Only in Demerara

While growing in other portions of South America and in the West Indies, greenheart is now logged only in Demerara, British Guiana. There it is most plentiful, reaching its best development on a strip between 2 and 3 miles wide, just back of the deposit of alluvial soil along the coast and rivers. The workable area from which it is cut is about

14 per cent of the entire forested area of Demerara, and is confined to the more accessible parts of the country, extending from the sea coast to the rapids and falls of the large rivers. In some parts of this area the stand has been materially reduced through overcutting; but the present government restriction, allowing no trees to be cut that square less than 10 inches, tends to provide for future crops in the old cutting areas.

Greenheart, in Demerara, is not under private ownership; the British government holds the entire stand. Private individuals, or companies, lease parts of the area, but they can sell standing timber only by permission from the Crown.

The tree attains a height of from 60 to 100 feet, the diameter ranging from 3 to 4 or more feet. The bole is generally clean and symmetrical for the first 50 or 30 feet. The tree, however, grows very slowly and one of the merchantable size (say 30-inch diameter) is about 250 years old.

Sizes and Forms Obtained in Woods

Since 1840 the average dimensions of export timbers seem to have remained fairly constant -- from 12 to 18 inches square, and 35 to 50 feet long. Timbers can be had up to 24 inches square and 70 feet long. The timber is generally hewed, and is often shipped from Demerara with a great deal of wane left on the edges near the smaller end. No allowance is made for wane in calculating the cubic contents of the logs.

Since the logs have to be hauled by hand over corduroy roads to the nearest stream, the operation is facilitated by hewing the logs, and by "sledging," "snaping," or "sniping" their butts; that is, a bevel is cut, beginning from 2 to 5 feet from the butt. Very often this end is not squared off before shipment abroad. The timber, however, does not taper as much as European oak, which adds to its favor among European contractors.

Carey sums up what seems to be the opinion of British engineers, that greenheart arriving in England is usually so misshapen and irregular in size that, as a material for piles, it cuts to great waste, thus increasing its cost.

Care Necessary in Seasoning

Care is necessary in seasoning the timber, owing to its tendency to check and split at the ends. The logs, however, do not check and split any more in seasoning than many other hardwoods in common use.

While awaiting shipment in Demerara, the timber is stored along the banks of tidal rivers where it is submerged at every flood tide. The majority of the logs lie on these flats one year before shipment or sawing. This treatment is given the timber in order to prevent the forest borers from injuring it. It seems to be good practice to specify that the logs shall be felled and hewed at least one year before shipment. This is supposed to insure a proper preparation for use, provided the logs after hewing are stored as described. This seems to be a method developed through experience, since, although foreign users never specify that the timber shall be seasoned at all, it is probable that the timber they receive has gone through the treatment described with entirely satisfactory results.

Difficult to Saw Greenheart

Some greenheart is sawed before shipment from Demerara. Baterden states that the wood of greenheart possesses a poisonous character, rendering care necessary in working it since splinters getting into the hands are known to have caused death. This property is not mentioned by any other writer and it is possible that Baterden had some other Demerara wood in mind. At least one other species from that region is reputed to yield a poisonous wood.

Greenheart is, however, a difficult timber to saw, owing to its tendency to splinter. Unless special saws are used in the mill, it may split from end to end in passing through them and when being converted into 2-inch plank may break short across the grain. These evils are prevented by cramping behind the saw. In crosscutting, the timber should be hooped with iron on either side of the proposed saw kerf. It is always necessary to support it under the kerf of the saw. If these precautions are not observed, flying splinters may seriously injure the men handling it. These remarks apply primarily to circular saws.

Overcoming Difficulties in Sawing

These difficulties have in recent years been overcome by the introduction into Demerara of self-contained vertical saw frames, with a 24 to 30 inch stroke and a roller feed. No other type is now used. Even with these special saws the conversion of greenheart is a difficult and slow operation so that the exporters prefer to ship hewed timber.

In sawing, it is estimated that only 1 cubic foot of material can be obtained from 3 cubic feet of hewed timber, if it is calculated that slabs, ends and occasional hollow logs can not be sold locally. In Guiana, however, the refuse has a high market value so that sawed timber, instead of selling for three times as much as the hewed, averages only from 70 to 115 per cent higher in price. In many cases the purchase of sawed timber is worth while since sawing removes the larger part of the sapwood and exposes defects.

Quality of Timber Exported

The best quality timber is secured from trees more than 2 feet in diameter. The timber is generally straight-grained and sound and remarkably free from knots. The freedom from knots is due to its naturally clean bole, and to the fact that the part above the first branches is seldom logged. The soundness of the export timber may be attributed in part to the method of paying the woodsmen who receive so much per tree for felling sound trees only and are, therefore, careful to avoid any that show the least suspicion of decay. Although the logs often check into four segments, the latter usually do not continue separate for more than 2 or 3 feet from the end. The split ends are generally cut off before shipment.

The sapwood of the logs is often attacked by a forest insect (presumably after felling), but the latter dies after the log is submerged, placed on shipboard, or landed in a colder climate. Since wormholes are indications of defective wood, timber thus attacked, especially that which is to be exposed to fungi or marine borers, had best be rejected. Sometimes large and deep borings are found in the interior of a piece, no trace of which is observable from the outside. These are the burrows of tropical insects, and generally render a piece valueless.

It is a tradition in Demerara that the inherent qualities of the timber improve with its distance toward the west in that country. That from the Essequibo River is considered best, that from the Demerara intermediate, and that from the Berbice inferior. It seems that the largest trees (which contain the best quality timber) are found in the Essequibo River valley. The smallest come from the Berbice River valley, but that locality has been cut over several times. It seems to have yielded good quality timber in the early days of greenheart exploitation.

To Secure Good Timber

Owing to the great demand for the timber abroad, and the lack of legal restrictions upon cutting in the past, it has become increasingly difficult to secure good greenheart from the areas below the falls and rapids of the numerous streams. Beyond these obstructions, however, are valuable untouched forests which transportation facilities might make available.

Before the timbers are loaded on the ship the checked or split ends are sawed off and the fresh ends bound with metal hoops, in order to prevent further checking. The freshly cut surfaces are painted with red or white lead over which 1-inch buffer pieces, covering the entire end of the log are nailed. The removal of the split ends entails much waste, although there is a local market for the refuse.

Cost is High

The price of greenheart always has been high but it is generally lower today than 70 years ago. The quality does not seem to have deteriorated, although the quantity exported each year averages about 200,000 cubic feet. The price of greenheart in 1913 delivered alongside ship, British Guiana, was reported as approximately 32 to 34 cents per cubic foot for 12 by 12 inch, short length, 50 to 55 cents for 20 by 20 inch under 45 feet long, and 65 cents to $1.20 for timbers over 45 feet long, depending on length and cross section. The price, therefore, varies from about $27 to $100 per 1000 feet board measure. These prices are for hewed timber and are uniform over long periods; in the 25 years previous to 1908 the cost of greenheart did not materially fluctuate. Sawed timber on the average will cost from 170 to 215 per cent more.

Cause of High Price

The high price of the timber is due to a number of causes. The expenses of prospecting for new areas in a wild country are great, and the cost of surveying, rent, and royalty must be borne by the operator. The trees are felled with the axe alone, since those felled with the saw are reported to be more liable to check and split. Since the wood near the ground is excessively hard and horny, the woodsmen cut to a high stump. It is, therefore, necessary to erect a scaffold at each tree, the latter being cut off 6 or 8 feet above the ground. Great care is necessary in felling, so that the tree will not split or break, or fall where it is inaccessible for squaring and removing. This adds greatly to the cost of logging.

Transportation is difficult. Hauling to the water is done by hand. Since greenheart is heavier than water, the logs have to be slung on punts, from two to four logs per punt on the smaller streams and 1000 cubic feet per punt on the larger watercourses. The logs also lie in storage for a year or more, thus tying up a great deal of the operator's capital.

The freight rates from Guiana in 1913 ran about as follows: To the United Kingdom by steamship, 24 to 30 cents per cubic foot, $6.72 to $8.40 per ton (of 28 cubic feet), or $20 to $25 per 1000 feet board measure; to the United States via steamship, 20 cents per cubic foot, $5.60 per ton, or $16.15 per thousand; and to the West Indies, by sailing vessel, 16 to 20 cents per cubic foot, $4.50 per ton, or about $13.50 per thousand.

The unusual properties of greenheart are manifested particularly in its structure, its great weight, its superlative strength and stiffness, its hardness and its great durability. In structure, the unmagnified cross section has been described as resembling that of cane and palm, the pores appearing very distinct. According to Baterden, the growth rings, which are often regular near the heart, spread out on one or both sides and run into one another becoming indistinct.

Color and Weight

The prevalent hue of the wood varies from a pale greenish yellow to a deep brownish purple. The freshly cut sapwood is pale yellow, turning upon exposure to dark greenish

or chestnut. From the sapwood to the heart the color gradually deepens, makes the distinction of sapwood from heartwood difficult to all but the trained eye. This is a matter of great importance since the sapwood is often in excessive proportion. In trees 12 inches or less in diameter, 6 feet from the ground, only a very small amount of heartwood is developed; in 18-inch trees the sapwood is 4 inches wide; in 24-inch trees, from 3 to 3-1/2 inches wide; and in 30-inch trees from 2 to 3 inches wide.

The wood and bark contain at least four alkaloids among which are bebeerine ($C_{18 or 19}H_{21}O_3N$) and nectandrine ($C_{20}H_{23}O_4N$). The acid content of a sample of greenheart submitted to the Forest Products Laboratory based on the air-dry weight of the wood, and calculated as acetic acid was 0.048 per cent. Teak, which is considered as corroding steel but little, contains 0.078 per cent of acid calculated in the same manner.

The specific gravity of the timber is given by various authorities as varying between 1.08 and 1.23, equivalent to from 67.5 to 75 pounds per cubic foot. A log tested at the Forest Products Laboratory had a specific gravity when green of 1.16, equivalent to 72.5 pounds per cubic foot. The air-dry weight (at 12 per cent moisture) was 62 pounds per cubic foot, and the oven-dry weight was 57.5 pounds. On the whole it is heavier than osage orange, the heaviest of the 130 species of American woods tested at this laboratory.

Shrinkage and Strength

The claim has been made that greenheart has little or no moisture in its fibers and far excels any other wood in its resistance to the absorption of moisture. Whatever may be the truth of the latter assertion, the green material tested at this laboratory contained at least 45 per cent moisture and shrank 13 per cent in volume from the green to the oven-dry condition, or about seven-eighths as much as white oak. This would lead to the belief that the above assertions are based on erroneous information. It is possible that the rate of shrinking and swelling is so low that the timber does not follow rapidly the changes in the moisture conditions surrounding it. This is true of oak.

Apparently an impression has been created abroad that the moisture content of the wood has no effect upon its strength. A small number of tests made at the Forest Products

Laboratory upon small, clear specimens taken from one log of greenheart gave the average values shown in the table herewith. They show that in small, clear pieces drying does increase the strength.

These results indicate that greenheart, as a beam or post, is 25 per cent stronger and 50 per cent stiffer than black locust, the strongest and stiffest of the 130 species of North American woods so far tested. In resistance to shock it falls considerably below the hickories, and classes with beech, birch, ash and oak. It is a tough wood, however. The increase in its mechanical properties from the green to the dry condition will probably not take place in large-sized pieces, owing to defects, like knots, which develop in all species of timber during seasoning.

Hardness and Inflammability

Greenheart falls among the hickories in hardness. It is about as hard as dogwood and black locust. It is harder to work than oak, planing well, turning hard and badly, polishing indifferently and taking nails badly. In Demerara green timber is always preferred, owing to the extreme difficulty of working the material after it has seasoned.

Greenheart is neither more nor less inflammable than any other timber of the same dry weight per cubic foot. But since it is very heavy, it is remarkably fire resistant. Its local name of torchwood, which seems to have arisen through special use, is, therefore, misleading.

Durability

The durability of the heartwood is great. This is well proved not only by the actual experience of those who have used it, but also by tests at the Forest Products Laboratory. The results of work with 23 wood-destroying fungi led to the conclusion that:

"The heartwood of greenheart proved highly resistant and in most cases practically immune to all of the fungi used, in spite of the fact that the organisms developed luxuriantly in the tubes. The sapwood proved far less resistant."

Records of durability show:

Scotland.--Piles at Glasgow and Leith are sound after from 60 to 80 years service, whereas longleaf pine of excellent quality is destroyed in from 15 to 40 years.

England.--Gates of Canada Lock at Liverpool were in service 38 years, were enlarged in 1894 and the same timber used, and still in service after 18 years' additional use. Total service to last report is 56 years. Some limnoria are reported at Liverpool.

Resistance to Marine Borers

The sapwood is not resistant to the marine wood borers. This is a matter of great importance, since the detection of weathered sapwood is difficult and the latter may be in large proportion. The shipworm and the crustacean borers (such as limnoria, chelura, and sphaeroma) undoubtedly attack greenheart.

In the Netherlands the attack in good quality timber does not proceed deeper than 3/4 inch, and ordinarily less. This may possibly be the width of the sapwood on squared timber, since something in the heartwood, possibly one or more of the alkaloids, seems to deter or kill the shipworm. The Netherlands engineers advance the statement that the calcareous lining of the shipworm's burrow is softened by something in the wood.

Records of Resistance

The following is a summary of records of resistance of greenheart to marine wood borers:

West Indies.--Piles sheathed with yellow metal at Barbados. Average life at Trinidad is 15 years.

British Guiana.--Flooring in slipway of dockyard was sound after 20 years and piles after 25 years. Log of bullet wood was riddled in one year. Teak and oak were destroyed in two years.

Netherlands.--Bearing, revetment, and fender piles and lock gates at 10 places on the coast give average life of 12-1/2 years with no shipworm attack deeper than 3/4 inch. Timbers in place from 2 to 29 years. Surinam geelhart piles were riddled in three years.

Belgium and France.--Piles and other under-water timbers, safety doors on lock gates, and bollards at four places average 13-1/2 years against shipworm and remain in good condition. Timbers in place from 6 to 24 years. European beech was riddled in one year.

Scotland.--Staging, test pieces, piles, and sill timbers, heel and miter posts at nine places on Scotch coast average 17 years against limnoria. Some were eaten throughout the entire surface after 3-1/2 years; some were not fit for reuse 11 years; and many were sound after 30 years. Longleaf pine at the same points averages about 11 years.

England.--Piles, paddles, and bracing at six points on the English coast average 20 years. All are reported in service after from 4 to 36 years, against shipworm, limnoria, and chelura. Longleaf pine of excellent quality was destroyed after an average life of 7-1/2 years, and janah after about 10 years.

Mediterranean.--One place recorded piling destroyed in 20 years.

Suez Canal.--An experimental piece of greenheart was sound after two years. An oak pile driven at the same time was badly deteriorated, and a fir pile was completely eaten away.

South Africa.--At one port wharf timber and piling showed an average life of 10 years against shipworm, limnoria, and sphaeroma. All joints in the bracing were eaten out by limnoria in eight years. Piles averaged 12 years. Longleaf pine has a maximum life of one year.

India.--Dock gates and piling at two places showed an average life of 14 years and ranged from 10 to 30 years. Teak was destroyed in an average of 12 years and longleaf pine in from four to five years.

General Uses

In Demerara the timber is used in the construction of houses, fences, wharves and board walks, and for paving blocks. It is the favorite wood for flooring, often lasting from 50 to 75 years without signs of wear. It is also the favorite wood with the wheelwright and shipbuilder. Large quantities of excellent charcoal are manufactured from it. In England it is used in bridge building, for carriage shafts, fishing rods, etc., and the "snaped" ends are worked up into motor-wagon spokes, belaying pins, etc.

In lock-gate construction greenheart, owing to its reliability, far outlasts iron and European oak, which are good for only about 25 years. Moreover, it has been calculated that the amount of greenheart timber necessary for lock gates is only about three-fifths that of European oak of good quality. In England greenheart is preferred to iron, although gates of the former are heavier and harder to move.

Examples of Use in Lock Gates

The lock gates at Buenos Aires are of greenheart, and its use in ports of the lock gates of the Panama Canal is of more recent occurrence. The wood is largely used for lock-gate construction in Scotland. It is practically the only timber used at Liverpool and Birkenhead, England, for piling and lock gates. The Manchester Ship Canal is regulated by 54 pairs of gates composed entirely of greenheart. The lower gates for the 80-foot lock at Eastham are built with triple panels. Each leaf weighs 265 tons complete in air. The chief engineer reported that from 1894 to 1902 the cost of maintenance averaged about $15 per pair of gates per year; and that the only elements in their construction limiting their life were the bolts and other fastenings, which could usually be renewed without serious difficulty. The Bridgewater Canal likewise has greenheart gates.

In the Netherlands greenheart is considered to be the best timber for lock gates as well as for piling. The engineers there recommend the following working stresses for lock-gate construction: Modulus of rupture, 2900 pounds per square inch; compression along the grain, 3200 pounds per square inch; horizontal shear, 255 pounds per square inch. Based upon the values for green material (which should always be used in the calculation of stresses in structural timber)

given above under mechanical properties, the factors of safety are about 6, 3, and 7-1/2, respectively. This is good practice, provided the material is of excellent quality.

The chief difficulty in its use for lock-gate construction is said to lie in its hardness, which tends to prevent the making of a water-tight joint.

Greenheart has many properties which recommend it to the European pile user. It comes in good lengths and is of nearly the same square cross section throughout its length. One objection to it is that it splits more easily in driving than European oak, but it can be rendered safe by tightly hooping the end under the hammer. In most cases the iron ring is allowed to remain after driving, owing to the tendency of the timber to check at the ends. However, instances have been recorded where piles not ringed showed almost perfect heads at the end of 12 years.

Some doubt has been cast upon the advisability of allowing piles to season before driving. It has been noted in Scotland that air-seasoned and weathered timber proved much less resistant to the marine wood borers than that used immediately upon receipt from Guiana. The former timber, however, may have contained a high proportion of sapwood.

Most Satisfactory Pile Timber

From the evidence at hand it is apparent that greenheart is the most satisfactory pile timber used in the borer-infested waters of northern Europe. In warmer climates its value is more doubtful, but even then it undoubtedly outlasts other species of commercial importance. It is necessary to consider that, in scanning data upon the life of piling, allowance must be made for the possible substitution of inferior species, or timber of poor quality. A shipment of sappy greenheart placed in a port would completely reverse the results that could be secured with heart timber.

Greenheart is in extensive use as piling in the British Isles, the Netherlands, France, and, to a smaller degree, Germany. It is about the only piling timber in use Demerara. It has been placed in service in the port works of LaGuayra, Venezuela, Rosario, and Bahia Blanca, Argentina, and Coatzacoaloos, Mexico. It has never been tried out for piling in the United States. The United States Forest Service has, however, installed several small pieces in the Gulf of